

SECTION 1

AMES RESEARCH CENTER

N78-29303

SR&T PROGRAM AND EARTH OBSERVATIONS

by

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INTRODUCTION

In this paper we present an overview of the research activities in earth observations at Ames Research Center and highlight some of the results of our FY '72 program.

Almost all of the tasks that will be described involve the use of our research aircraft platforms. The aircraft are used in three ways: (1) As intermediate platforms in the development of future satellite instrumentation, (2) as platforms for the development of techniques that are uniquely suitable for aircraft, and (3) as vehicles for the obtaining of data directly from the atmosphere through which the aircraft fly.

Our program is also directed toward the use of the Illiac IV which will be installed at Ames Research Center within the next few months. We have several environmental modeling programs underway and within six months they should be developed to the point requiring the capabilities of the Illiac IV to extend them to three dimensions.

Most of our SR&T tasks are heavily weighted toward Pacific coast and Pacific basin problems. In particular, we have developed a very close and formal relationship with the State of California resource agencies in which we will be lending them whatever talents and facilities we have in earth observations in an effort to help solve some of their very difficult resource management problems.

The SR&T effort at Ames presently involves some thirty researchers. Most of the work is being done in-house or through collaborative arrangements with Universities and government agencies. The tasks can be grouped for convenience into water applications, air applications, animal migration studies, and geophysics.

WATER APPLICATIONS

In water applications the principal activity revolves around the airborne differential radiometer system that was discussed in a preceding paper. In brief, the differential radiometer operates by tuning one channel to the wavelength of the material that is to be sensed and tuning the other channel to a reference wavelength. For example, one channel can be tuned to the chlorophyll A absorption band and the other channel can be tuned to an unaffected reference wavelength. With this device several lakes in the state of California have been over-flown, considerable ground truth has been obtained, and it is found that the output of the differential radiometer is proportional to the logarithm of the chlorophyll concentration. Figure 1 shows the use of this instrument in determining the characteristics of the outflow plume of the Sacramento and San Joaquin rivers through the Golden Gate of San Francisco Bay. Figure 2 shows the use of this instrument in plotting the distribution of chlorophyll in Clear Lake. Figure 2 also illustrates the result that can be obtained by the use of a dual channel television system utilizing false color intensity-slicing for real-time viewing of the chlorophyll distribution in bodies of water. This dual channel instrumentation has also been applied to the problem of detecting and measuring the extent of oil slicks. The problem is to determine what conditions can provide the greatest contrast between the oil and the water. The spectral characteristic of the reflected sunlight was examined as was the effect of polarization, the effect of sun angle and the effect of sky brightness. It was found that the reflected sunlight has highest contrast in the ultraviolet and that by using the polarization characteristics of the reflected beam one could further increase the contrast. Figure 3 shows a flight over two oil slicks with a differential radiometer which has one channel tuned to the UV and the other channel tuned to a reference wavelength in the visible.

We have also had a more concentrated activity at one specific lake in California, Lake Tahoe. This is a very clear lake with relatively sterile water; it is now experiencing a great deal of pressure from urban development at both the north and south ends. There is some concern that the lake is starting to become more eutrophic; and, in fact, algal blooms have been observed. One theory is that the algae are growing because of the nutrients that are carried by tributaries discharging into the lake. Therefore, this study, which was done in collaboration with the University of California, was directed toward an analysis of this particular hypothesis. Ames Research Center conducted the photographic over-flights and interpretation of photographs, the University of California team provided the ground truth, analyzing

the water samples for nutrients and bacterial and algal productivity. Figure 4 shows that the major discharge period is in the spring and early summer during the thaw of the Sierra snow pack. Figure 5 is one of the aerial photographs clearly showing the sediment plumes discharged into the south end of Lake Tahoe by the upper Truckee River. Figure 6 shows contours of the density of sediment in the plumes, together with some of the analyses of productivity. You will notice that there is a fair correlation between the density of sediment and the productivity of bacteria.

Recognizing that the primary source of water in California is the Sierra snow pack, we are developing techniques to measure the thickness of the pack and the water content. Because of the economic importance of the snow pack, forecasts of the year's water supply are important to many people; therefore, a fairly accurate accounting of the water content of the snow pack would be a very valuable contribution. A plane radio wave impinged on the surface of the snow is partially reflected and partially transmitted. The amount transmitted depends upon the thickness of the snow, the frequency of the radio wave, and the density of the snow. The technique that we are using was originally developed to study subsurface layers on the moon; we have done extensive computer modeling to see how this technique could be applied to measuring a snow pack. Figure 7 shows the geometry of the model. Figure 8 shows one of the traces determined by our theoretical modeling program. You should note that as the frequency is varied, a dip occurs at a frequency that is characteristic of the thickness and the dielectric constant of the snow. The depth of that dip is characteristic of the dielectric constant; therefore, the dielectric constant can be determined and, subsequently, the depth of the snow pack. The dielectric constant itself is a function of the snow density and therefore provides us information on the water content. Notice also that at regular quarter-wave intervals, additional dips are seen, and eventually a dip is seen (labeled ν_{ice} in the diagram) which is characteristic of the thickness of the ice under the snow pack. Therefore, ice thickness can also be measured with this technique, even under a snow pack. We are testing this technique using towers in the snow region. Instead of scanning the frequency, however, we're using a fixed frequency and fixed transmitter power and monitoring the reflected amplitude of the signal as the depth of the snow pack increases. You can see in figure 9 the results of one preliminary run where we do get the frequency dips that the model predicts; there is a marked difference between moist snow and very wet snow. These are very preliminary results, of course, and we will continue this investigation throughout the winter.

AIR APPLICATIONS

We have several tasks in the general category of atmospheric applications. The first of these tasks is an effort to determine the environmental impact of such operations as the SST and the Space Shuttle on the stratosphere. At the same time we wish to learn about the impact of lower atmosphere sources such as volcanoes, thunderstorms, and smog. In this effort, we are constructing theoretical models and developing instrumentation (to be flown on the U-2) to make analyses of specific gases in the stratosphere. The modeling program, as you can see in figure 10, will account for a number of constituents. In addition to those listed, we currently include many carbon compounds. The series of continuity equations that make up this model take into account time dependence, photochemistry, and mass transport. To date, we have developed a one-dimensional version of this model; it is on the computer and appears to be operating correctly. Figure 11 shows the results of using this model to determine the equilibrium stratosphere. Notice that the ozone concentration, which is one of the products of this model, agrees fairly well with measurements and with other steady-state models. Figure 12 shows the effect of introducing excessive amounts of nitric oxide and water vapor at 20 kilometers, which is the hypothesized altitude. A considerable amount of nitric oxide was introduced in this model and yet, as can be seen, there is very little impact on the ozone profile. These are, of course, very preliminary results and illustrate more the capabilities of the model than the actual evaluation of the impact of an SST on the stratosphere.

Figure 13 illustrates the sampling equipment that is being developed for the U-2. We will be able to analyze the atmosphere for CO, CO₂, ozone, water vapor, and nitric oxide. This package is being flown on the Ames 990 in order to debug it. Results to date have possibly established an upper limit for the nitric oxide concentration at 10 parts per billion at 39,000 feet (tropopause was at 33,000 feet). This information will serve at least to bound some models. We have also obtained some aerosol collections at this altitude. The particles in figure 14 are all one micron or less in size, the largest particles that you can see appear to be droplets; when they are touched by the electron beam for analysis, they deform and move around on the slide as droplets should. Approximately 1/3 of the particles are clearly droplets, perhaps another 1/3 are solid with liquid surface and perhaps another 1/3 are solid. The preliminary analysis that we have made accounts only for elements over atomic weight 11; we find silicon, aluminum, calcium, iron and sulphur. The large droplets contain only sulphur (probably sulphuric acid), the smaller particles contain the metals as well as sulphur, and the smallest particles apparently do not contain

sulphur. This would seem to indicate a fairly strong influx of volcanic material into the stratosphere. This again, however, is only preliminary information and cannot be viewed as definitive.

A second task in the area of air quality is an airborne survey of the vertical structure and areal extent of photochemical smog in the Los Angeles and San Francisco basins. These data are intended for use as input into revised air pollution models for these areas. In brief, we have instrumented an aircraft for the collection of carbon monoxide, nitric oxides, ozone, temperature, dew point, hydrocarbons and aerosols. Figure 15 shows the layout of these instruments in a Cessna 401A which was used for the surveys. Figure 16 shows a typical ozone stratification observed at Riverside. Notice that the concentrations of ozone at the inversion layer at approximately 2,000 feet are much greater than those at ground level. Figure 17 shows a survey flown 200 nautical miles west of the coast of California; here we see that ozone occurs at several levels and that a particularly high concentration exists at an altitude of almost 20,000 feet. It was also found that smog is dispersed several hundred miles away from each of the basins that were investigated. This work is being done in cooperation with the University of California at Riverside and with the San Francisco Air Pollution Control District and with the Livermore Laboratory of the University of California.

Another task in this area, a rather unique one, is the study of atmospheric microorganisms. The work done this summer revolved around the larger NASA study of the Midwestern corn blight. Two aircraft were instrumented to make collections of microorganisms. Figure 18 shows the area flown by an Aerocommander instrumented with an aerosol collector and figure 19 shows the area flown by a DC-3, instrumented with a different kind of collector. The result indicated that there were microorganisms over all the three states that were surveyed, that these organisms occurred in strata, that they were found at altitudes as high as 6,000 feet, and that they were frequently concentrated at the base of clouds. One of the difficulties that was encountered early in the survey is that the researchers were looking for the spore shown in figure 20 and could not find any in the collected slides; figure 21 shows a typical collection. Now, if one will notice the body in the middle of that collection and compare it with figure 22, you will see that it actually was a dehydrated form of the corn blight spore. When this was recognized, it was realized that all the collections had been successful; now there is a large body of data being analyzed to show the distribution, vertically and horizontally, over the corn-growing states.

Another task in this area that is just starting is a study of the atmospheric mercury budget for the San Francisco Bay area. This mercury study is now in the planning stage.

ANIMAL MIGRATION

Work in animal migration studies is just starting. The objective of the three tasks that are now getting underway is to study the migration of marine animals, utilizing the unique advantages of the satellite for long distance relaying of information about the global distribution and migration paths of the particular species under study.

The goal of the first task (figure 23) is to study the behaviour of whales. Since whales migrate over most of the globe, the use of a satellite is uniquely necessary for such studies. The second task (figure 24) is an attempt to use dolphins as platforms to carry instrumentation down to the biomass and to study its characteristics and extent. Inasmuch as dolphins must eat, they will find the biomass; and inasmuch as they surface often, the information could be picked up through telemetry. The third application (figure 25) is for the tracking of salmon in the northwestern United States. The management of the salmon harvest is a very difficult one and requires data on the number of salmon moving into the salmon fishing grounds. These particular data must then be analyzed in terms of parameters that are needed for management decisions; and this often must be done in just a matter of hours. This task involves the development of sonic bouys to be anchored along the Aleutian chain which can detect the number of salmon moving into the area (and perhaps their species and size) and relay this information via satellite to a large computer where the management program is stored; the results then would be relayed back to the fisheries managers.

We are also planning programs that involve the application of miniaturized physical function sensors to the studies of the behaviour of mammals during their migration and feeding.

GEOFYSICS

The first task is the use of vector magnetometry to analyze various geological characteristics under the surface of the oceans or below the surface of the land areas. We have used this vector magnetometer in a flight over the Pacific Ocean; the data will be used in analysis of sea floor spreading, and thus provide some information to corroborate theories of plate tectonics. We have also overflowed the United States and this data is being requested by NOAA as input to their world geomagnetic maps. In collaboration with the USGS, we made a very thorough magnetic survey of the northwestern corner of the state of Washington in the vicinity of Neah Bay.

The second task is a study of the application of thermal infrared instruments to the problem of detecting and mapping potential landslide areas. This appears to be feasible because landslide areas are caused by the underground damming of water drainage. The resulting differences in soil moisture cause changes in surface temperatures and these can be detected with thermal infrared sensors. Our preliminary studies have shown that this technique is very feasible and valuable; it is being continued in collaboration with the US Corps of Engineers and the State of California.

STATISTICAL CORRELATIONS

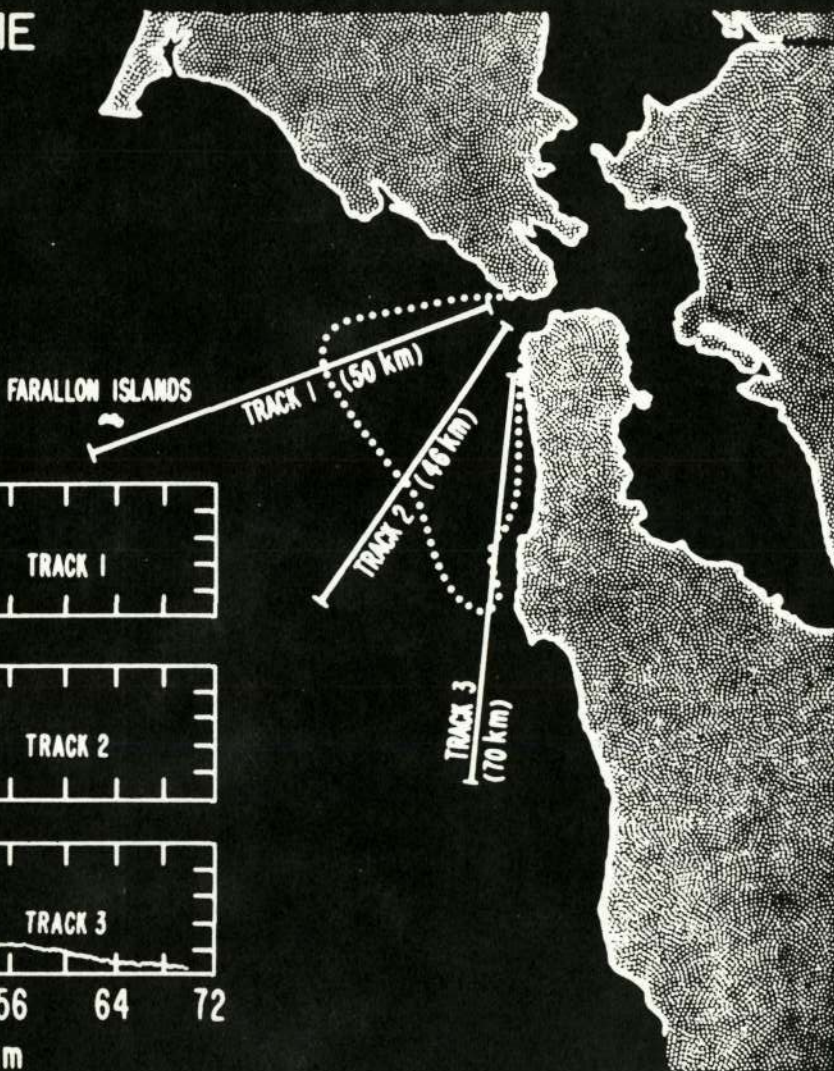
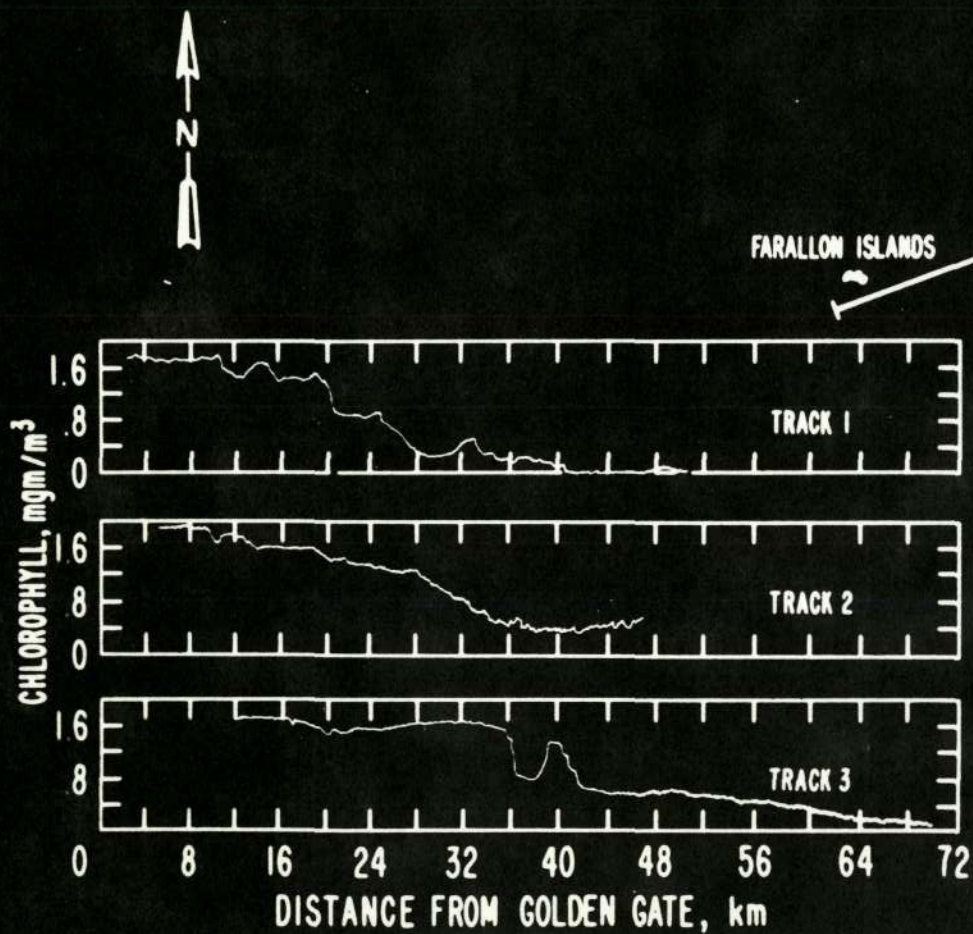
The last task is the development of techniques for the analysis of statistical data. The objective of this study is to provide computer techniques that will allow the determination of statistical relationships between variables whose relationships are unknown. Figure 26 illustrates a three-variable relationship plotted in three-dimensional space. It is very noisy data, and no apparent relationship is evident to the naked eye. However, when this data is processed with the program developed in this task, we see that this is a noisy spiral (figure 27). This sort of analysis, we believe, will be very valuable in attempts to correlate many ecological parameters that are being measured, and for which no known relationships exist.

Figures

Figure

- 1 Outflow plume from San Francisco Bay
- 2 Chlorophyl map of Clear Lake
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- 21 Typical Collection
- 22 Dehydrated Corn Blight Spores
- 23 Whale Migration Study
- 24 Biomass Studies with Dolphins
- 25 Salmon Tracking Studies
- 26 Three variable Statistical Relationship
- 27 Noisy Spiral

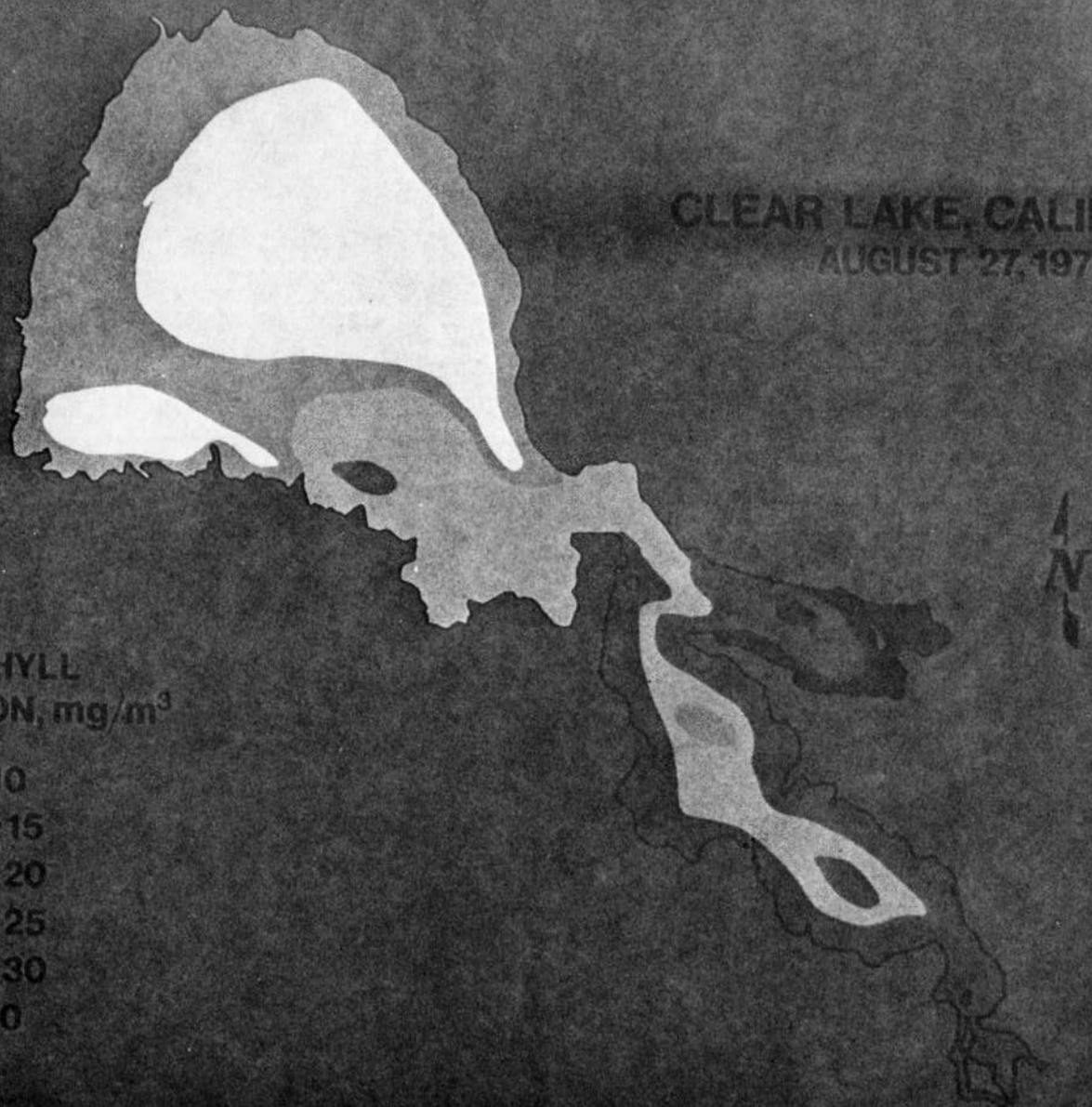
SAN FRANCISCO BAY PLUME FEB 23, 1971



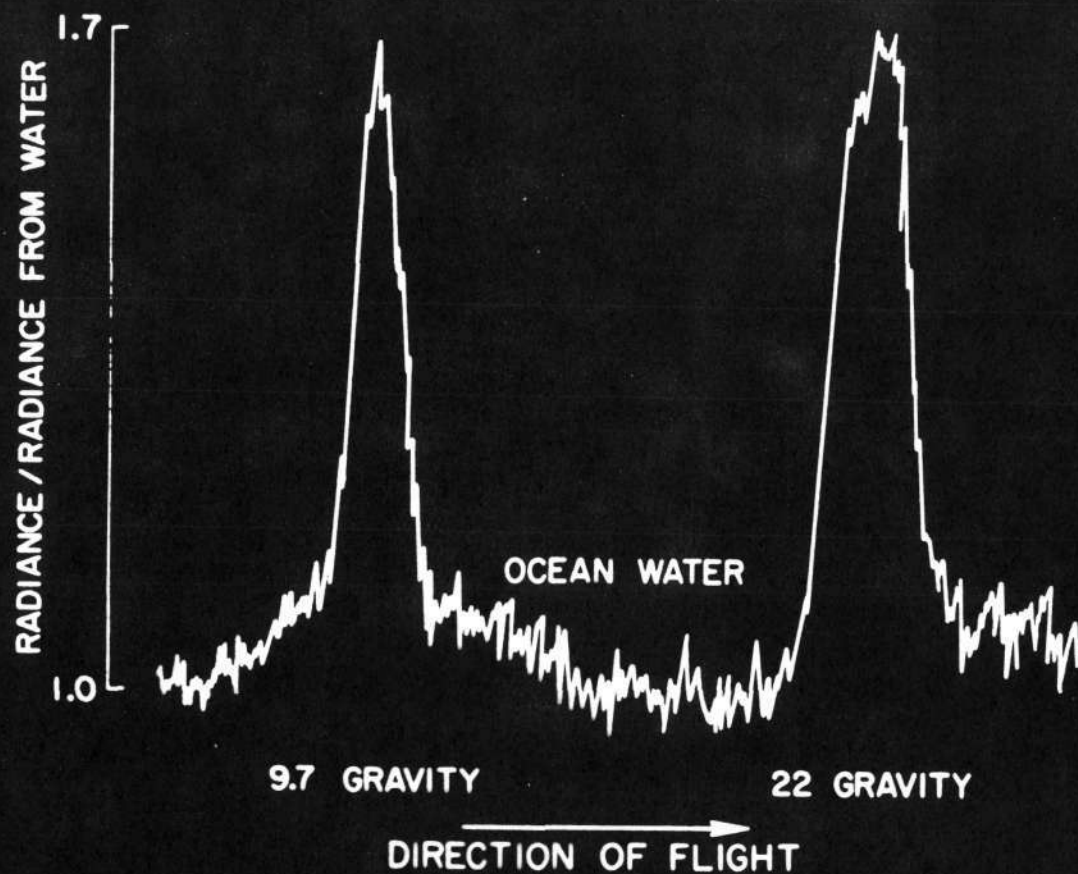
ARVESEN-5

CLEAR LAKE, CALIFORNIA
AUGUST 27, 1971

CHLOROPHYLL
CONCENTRATION, mg/m^3

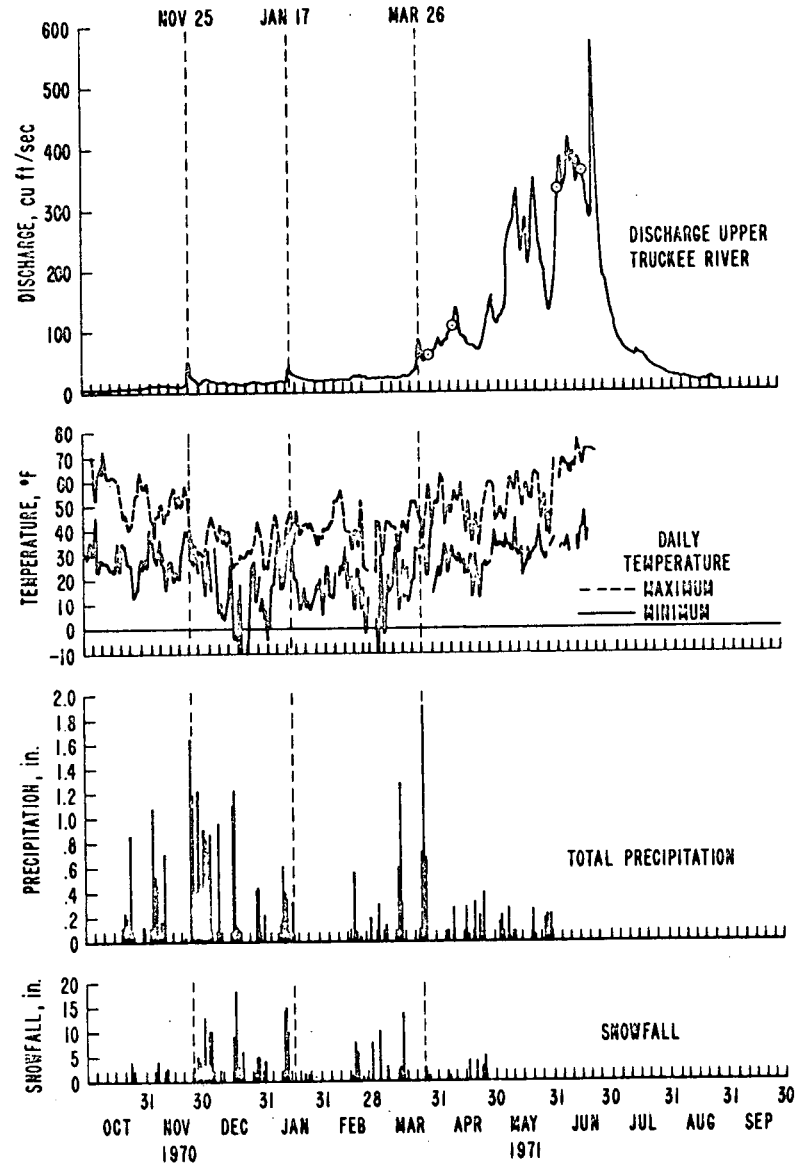


RADIANCE RATIO OF OIL-COVERED TO NATURAL
SEA WATER AT 400 nm
OCT 23, 1970 OVERCAST SKIES



ARVESEN-7

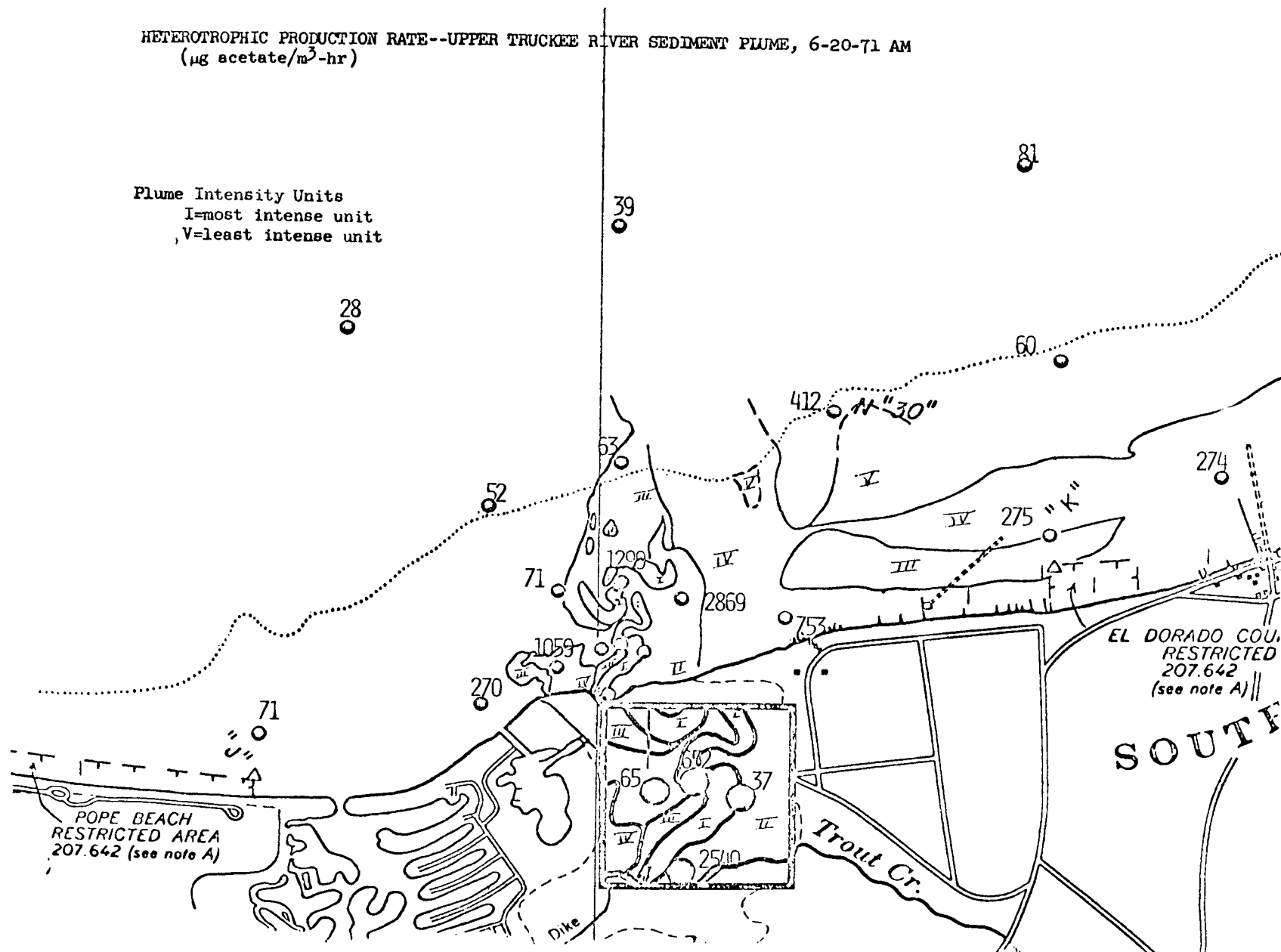
UPPER TRUCKEE RIVER NEAR MYERS, CALIF WATER YEAR 1971



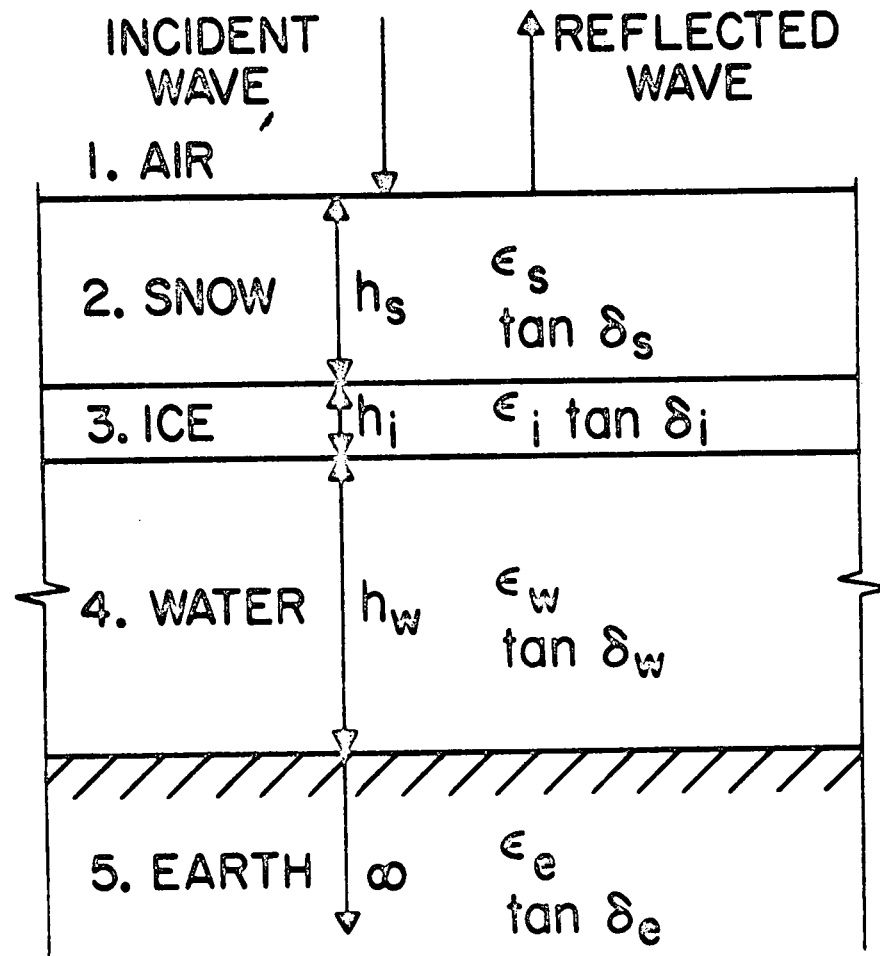


HETEROTROPHIC PRODUCTION RATE--UPPER TRUCKEE RIVER SEDIMENT PLUME, 6-20-71 AM (μg acetate/ $\text{m}^3\text{-hr}$)

Plume Intensity Units
I=most intense unit
,V=least intense unit



FIVE-LAYERED MODEL

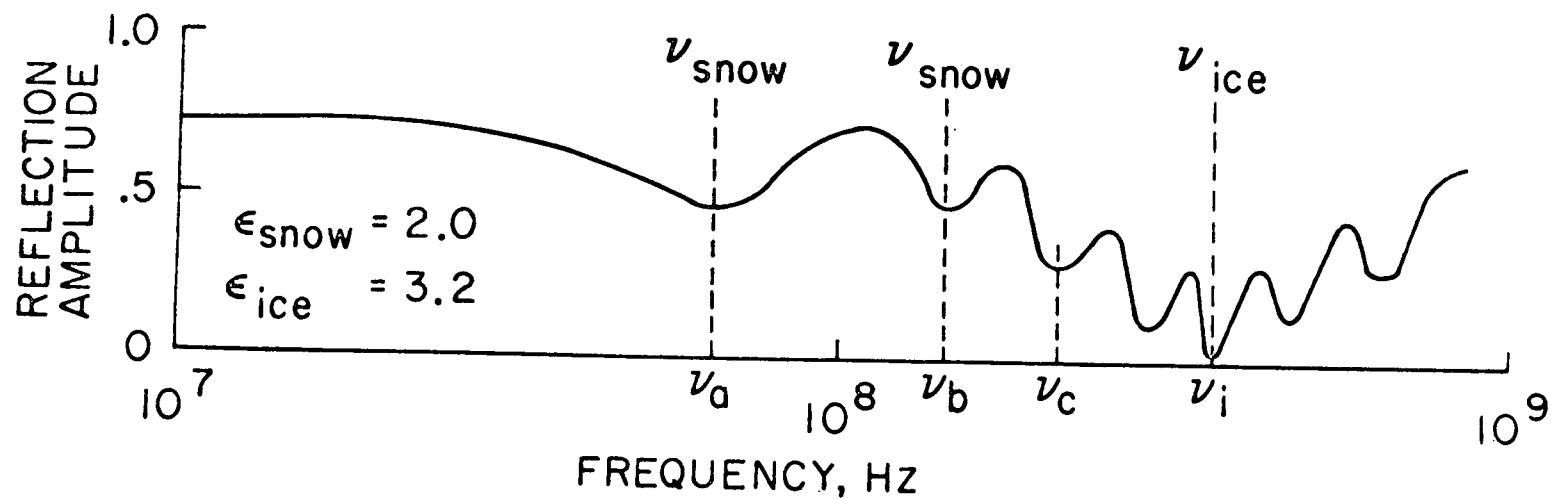


REFLECTION AMPLITUDE vs. FREQUENCY

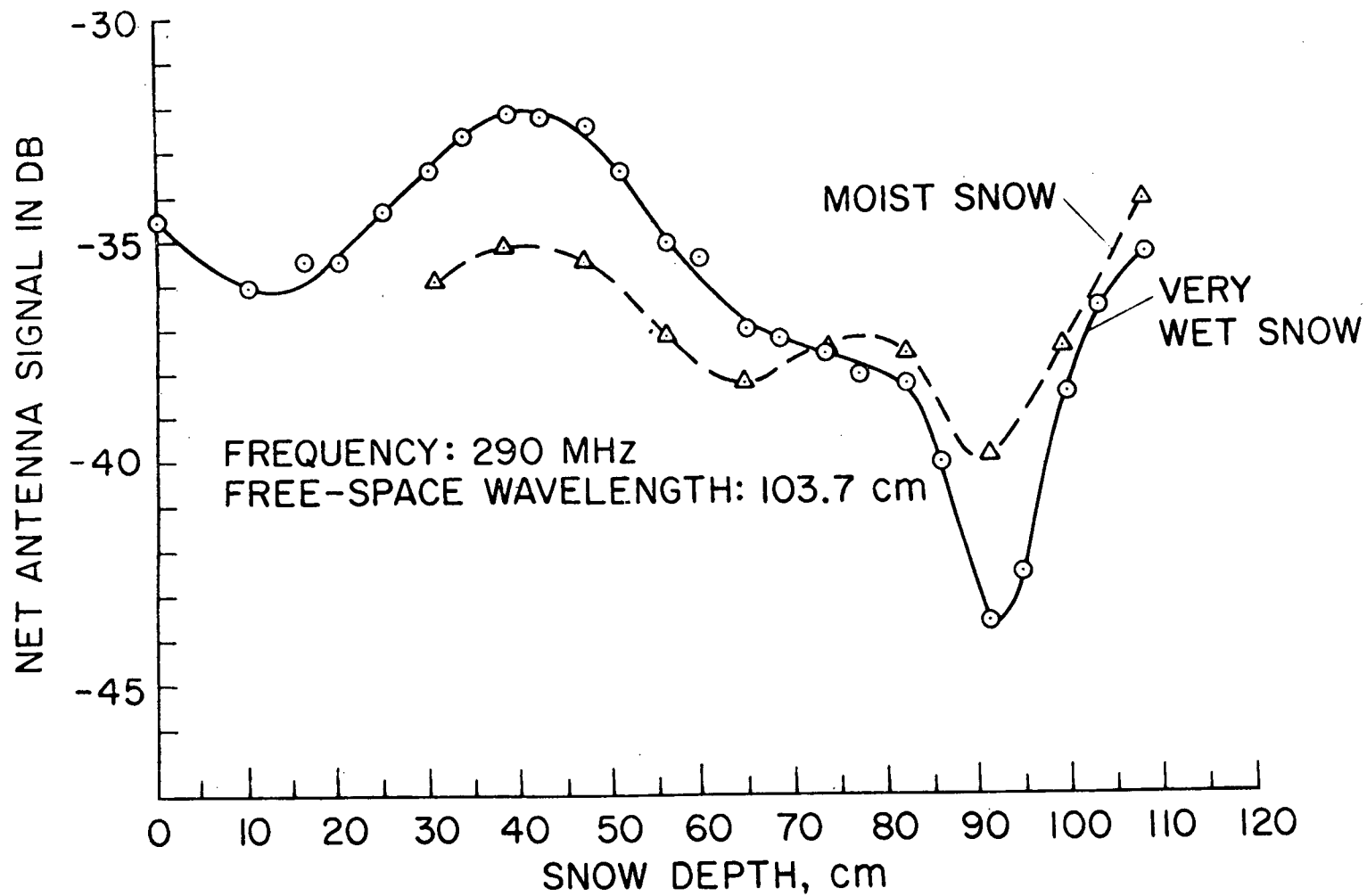
SNOW THICKNESS: 91.4 cm (3 ft)

ICE THICKNESS: 7.56 cm (3 in.)

WATER DEPTH: LAKE



SYSTEM RESPONSE VS. SNOW DEPTH



CHEMISTRY AND TRANSPORT

CONSTITUENTS:

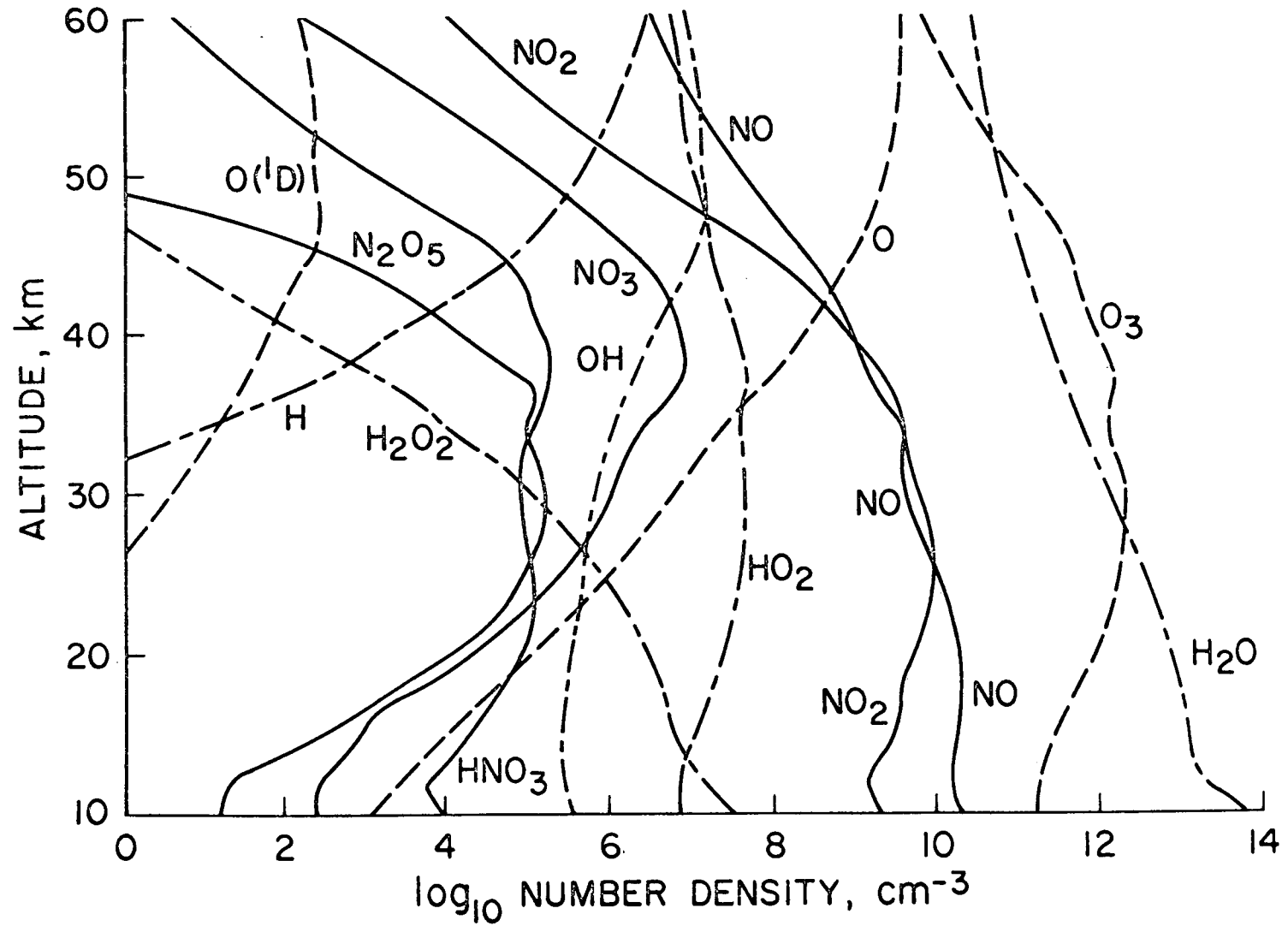
O, O (¹D), O₃, H, OH, HO₂, H₂O₂, H₂O, NO, NO₂,
NO₃, N₂O₅, HNO₃

CONTINUITY EQUATIONS:

$$\frac{\partial M_i}{\partial t} + \frac{\partial \Phi_i}{\partial z} = P_i - L_i$$

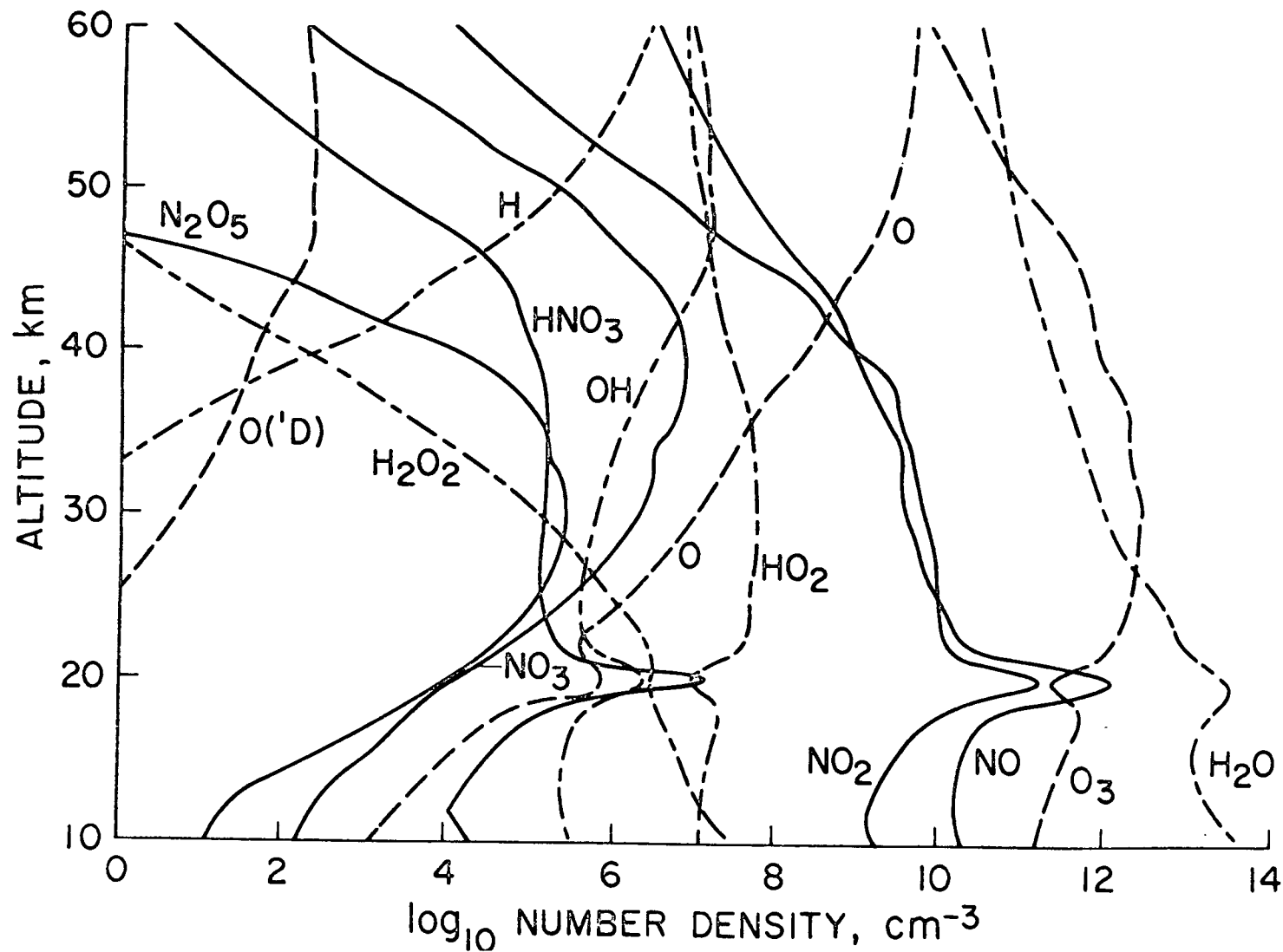
$$\Phi_i = -K \left[\frac{\partial M_i}{\partial z} + \left(\frac{d(\ln T)}{dz} + \frac{1}{H_i} \right) M_i \right] + VM_i$$

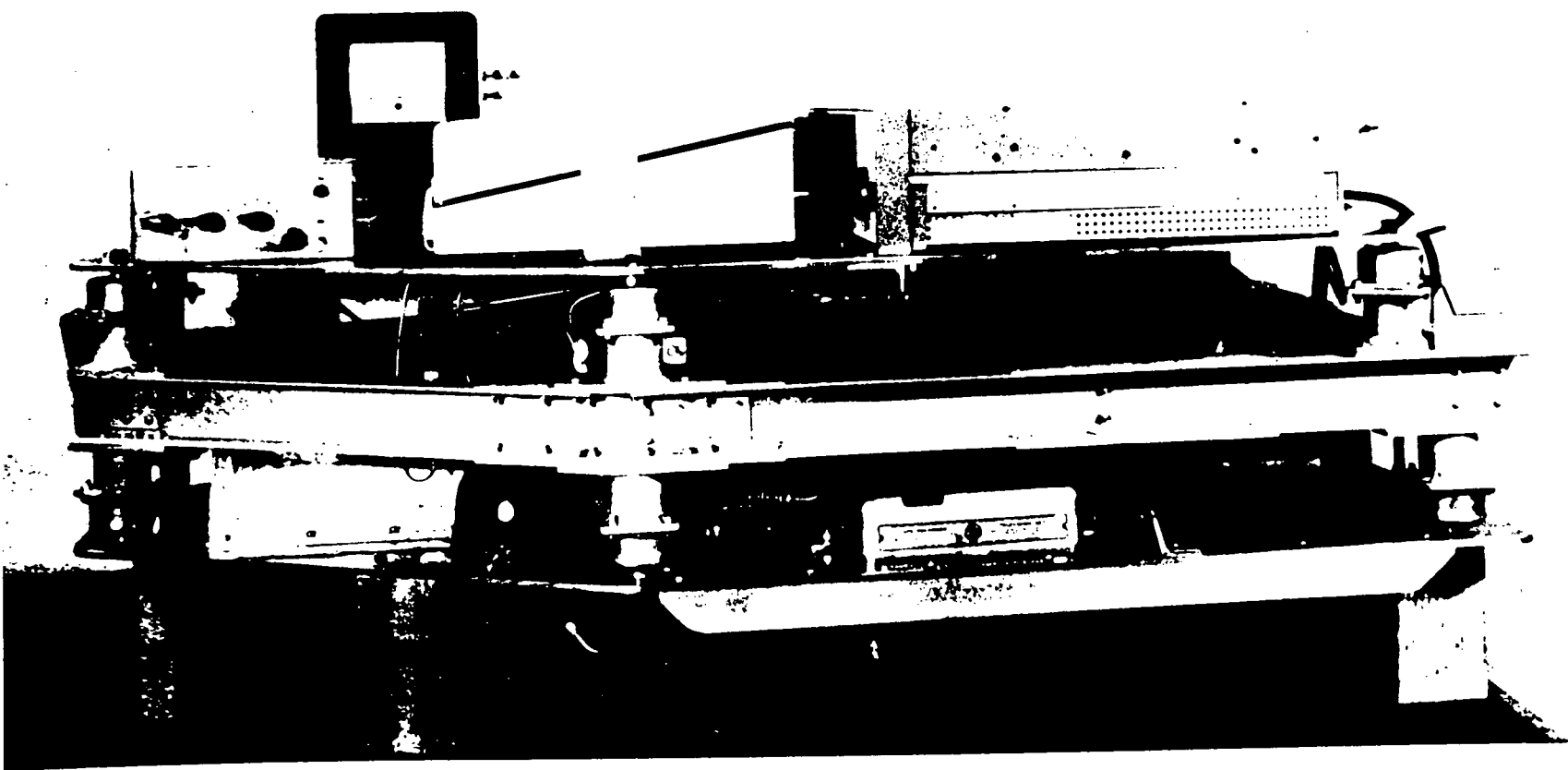
STRATOSPHERIC MODEL EQUILIBRIUM, DAYTIME

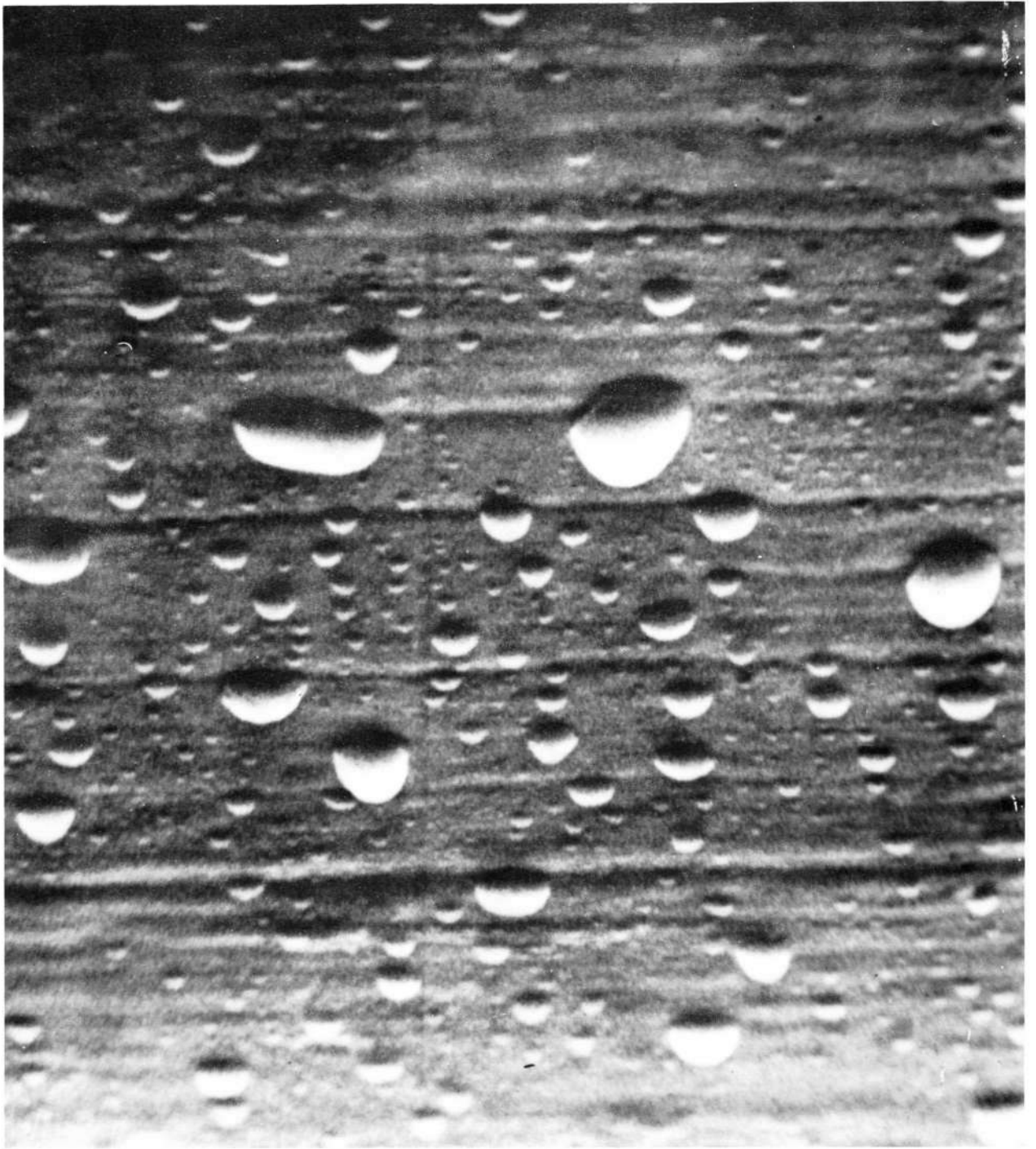


PERTURBED STRATOSPHERE AFTER 3×10^7 sec

1-20



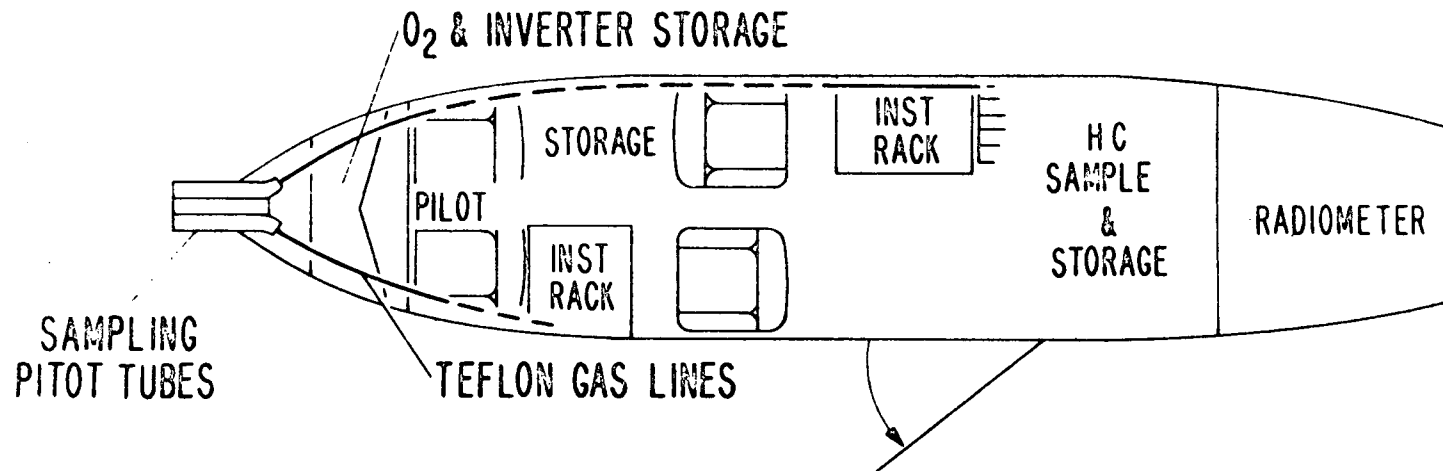




CESSNA 401-A CONFIGURATION

FALL 1971 FLIGHTS

EQUIPMENT WEIGHT-440 lbs
GROSS WEIGHT-6400 lbs



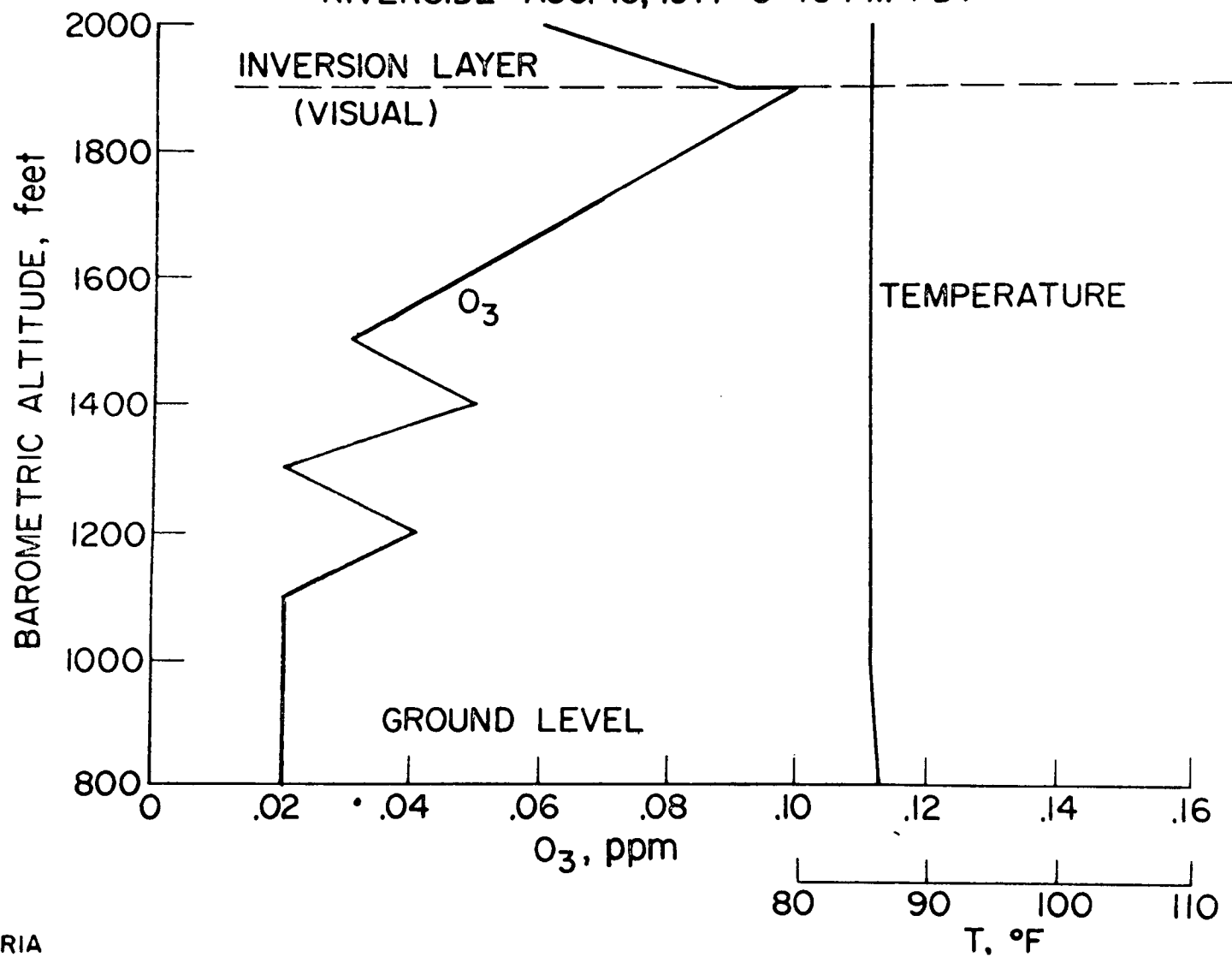
INSTRUMENTATION: CO
NO_x
O₃

TEMPERATURE
DEW POINT
RADIOMETER

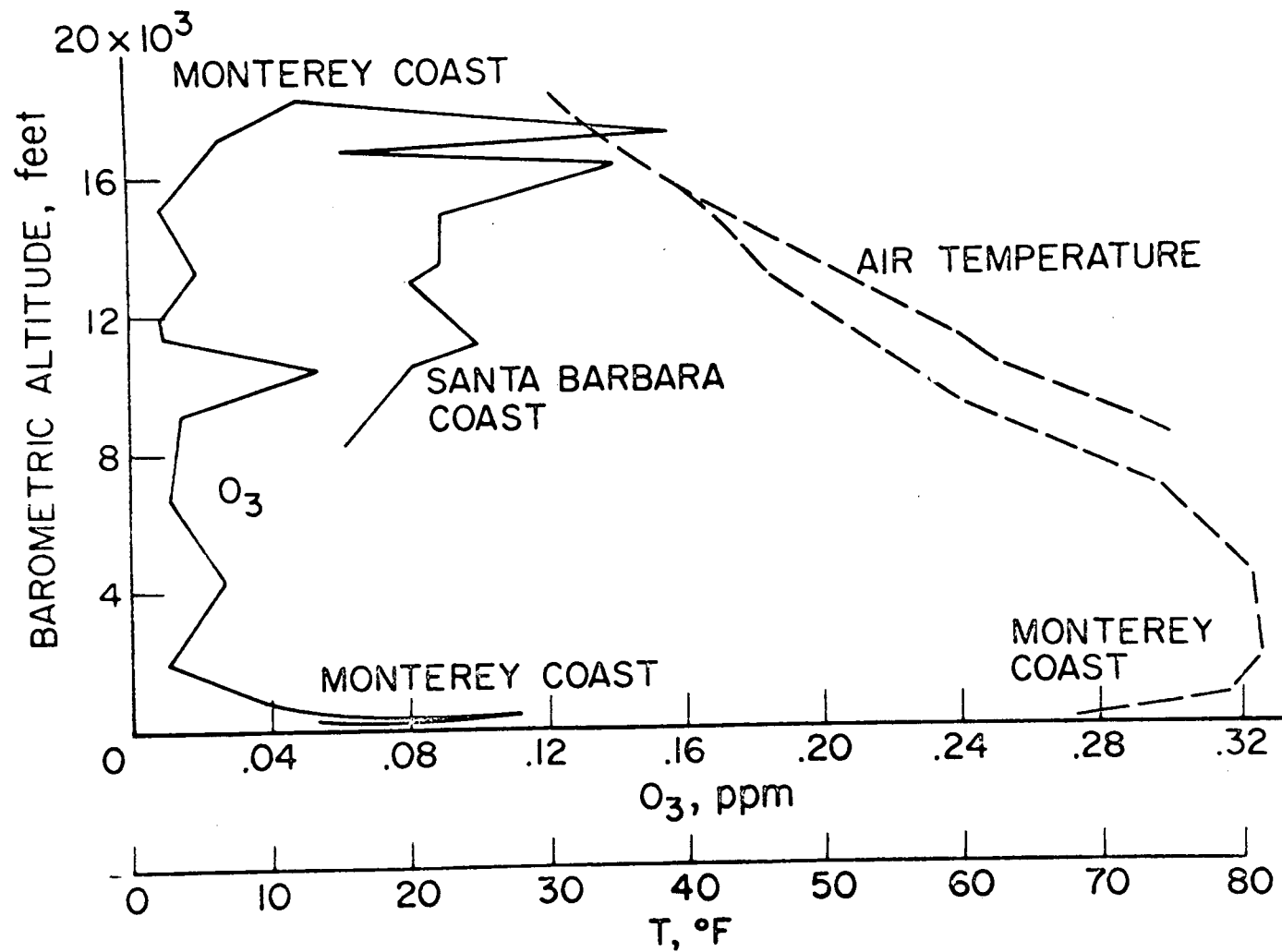
HYDROCARBON SAMPLES
NEPHELOMETER
RECORDERS

H. GLORIA

TYPICAL OZONE STRATIFICATION OBSERVED
RIVERSIDE-AUG. 10, 1971-5:46 PM PDT

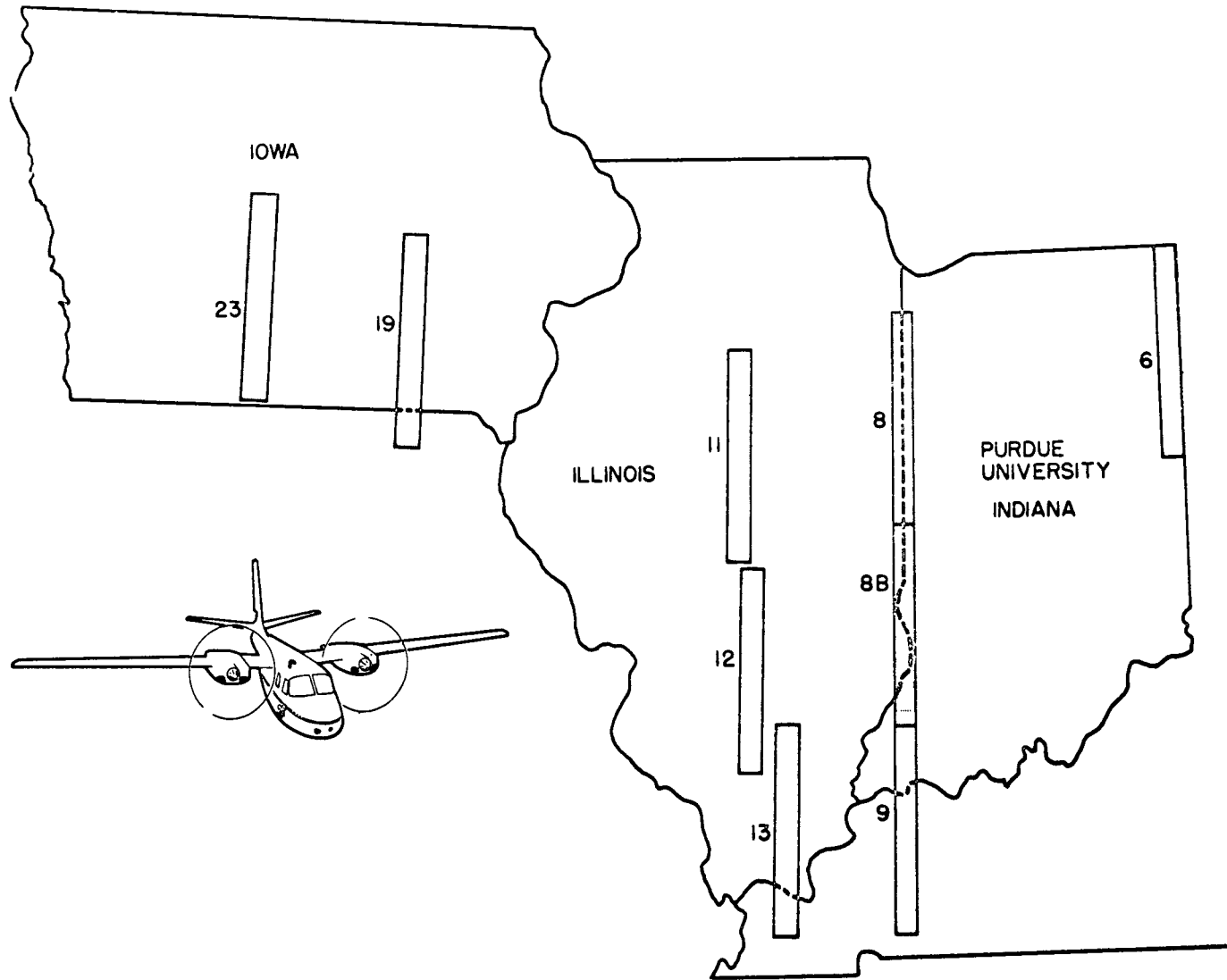


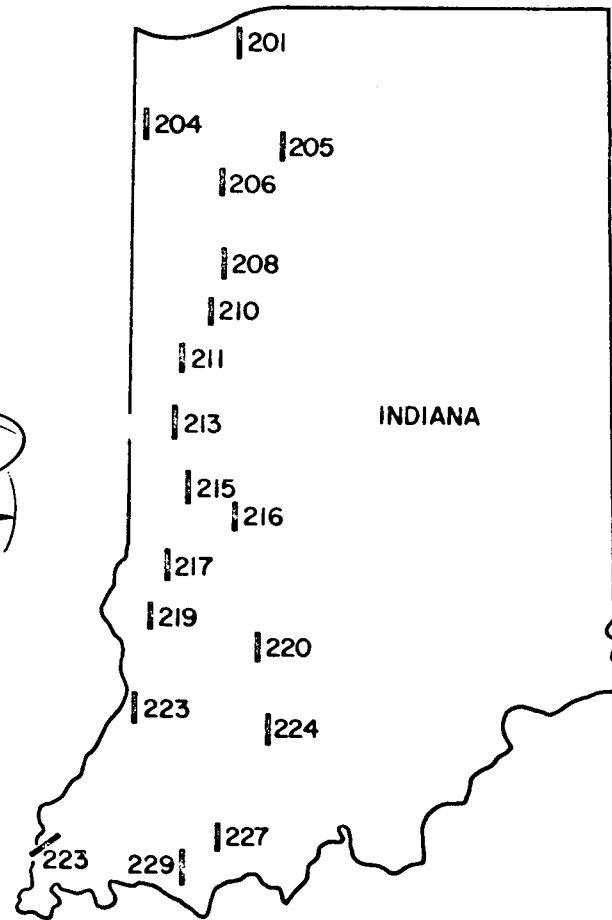
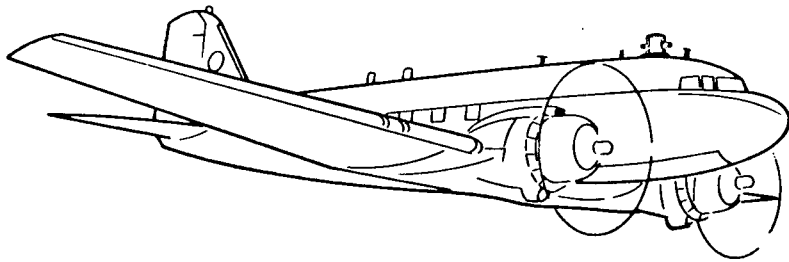
OCEAN BACKGROUND OXIDANT SURVEY
200 NM WEST OF COAST - FLIGHT 9A
SEPT. 11, 1971 - MIDAFTERNOON DATA



H. GLORIA

SAMPLING AREAS COVERED BY AEROCOMMANDER

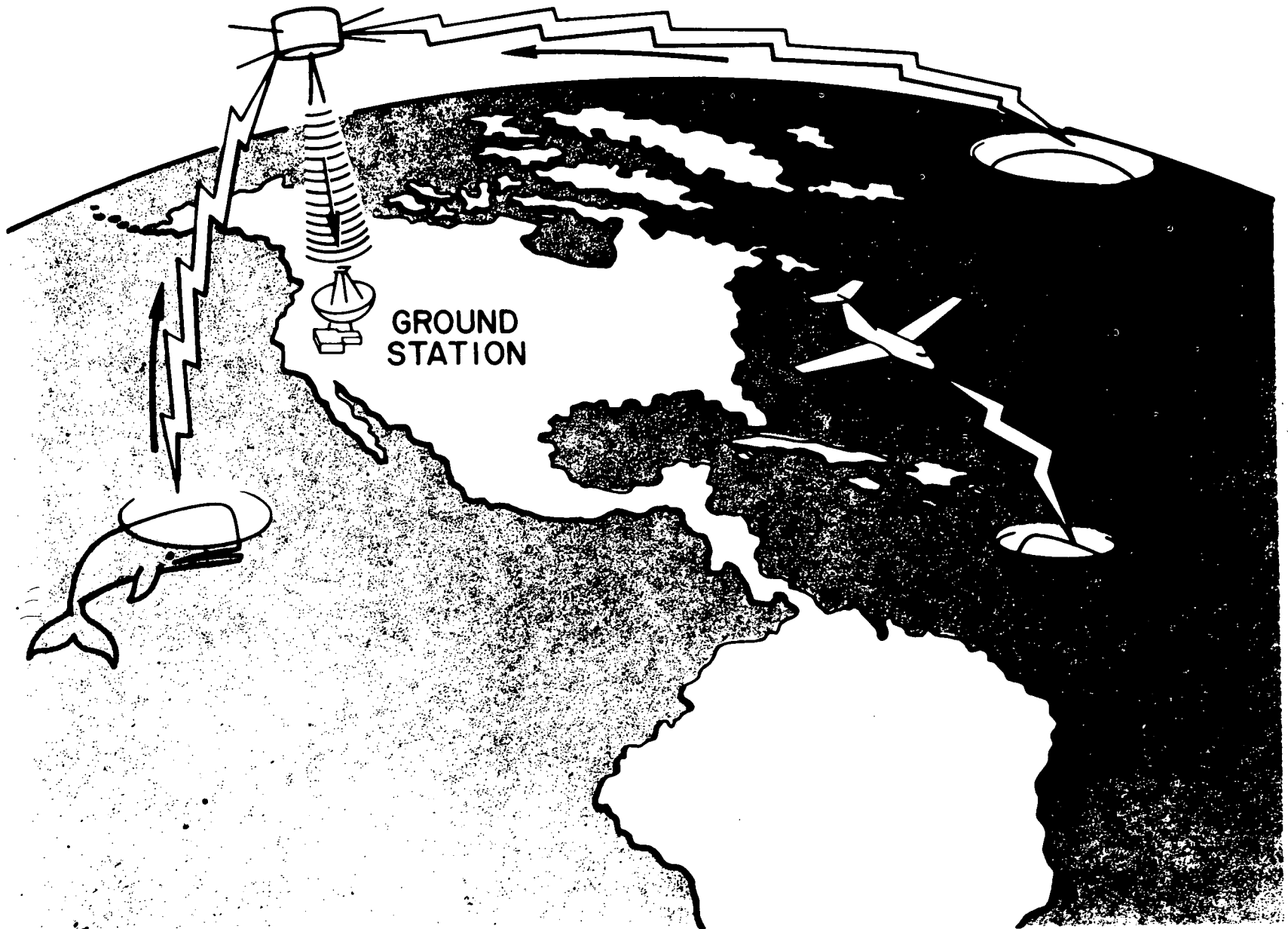


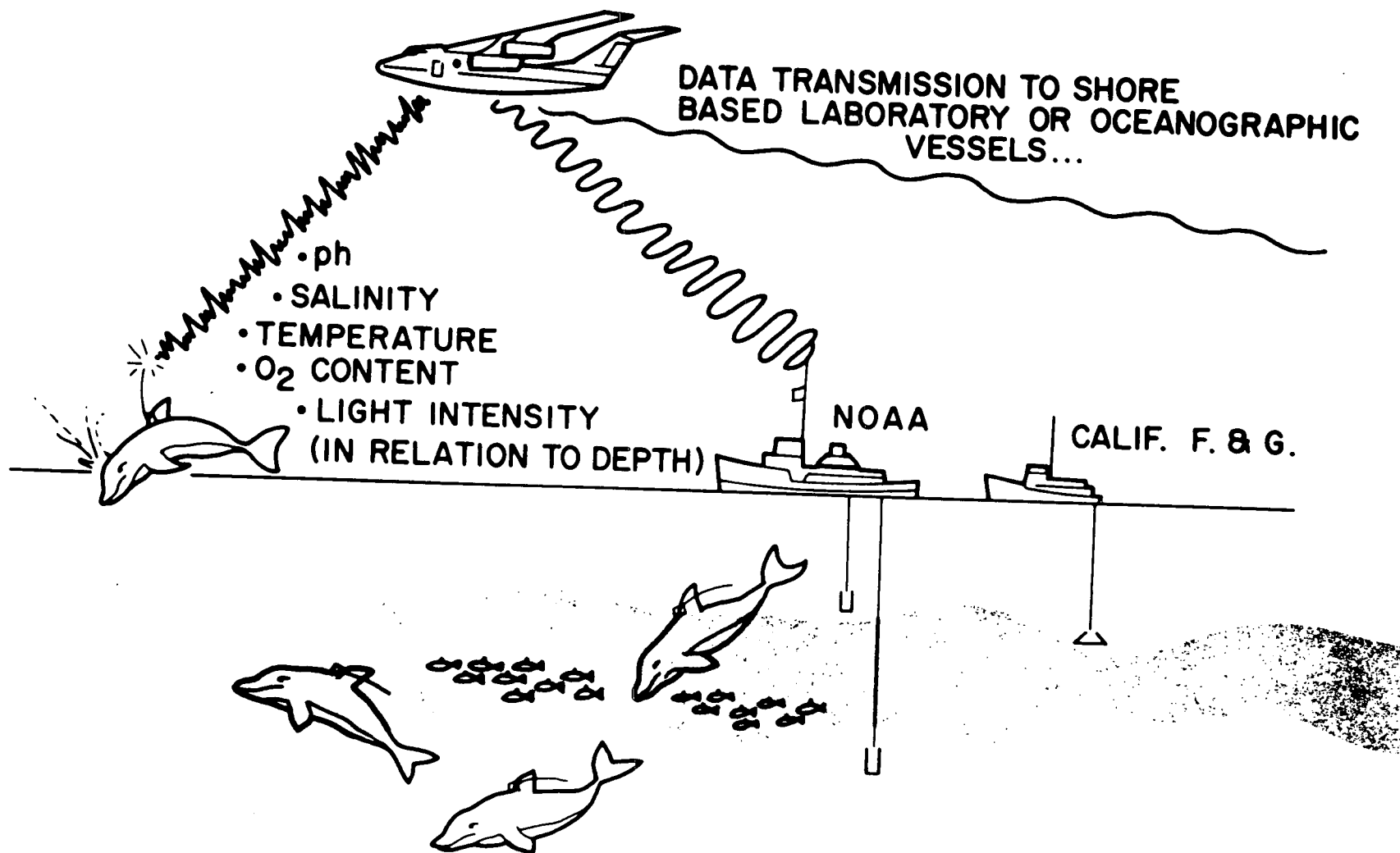


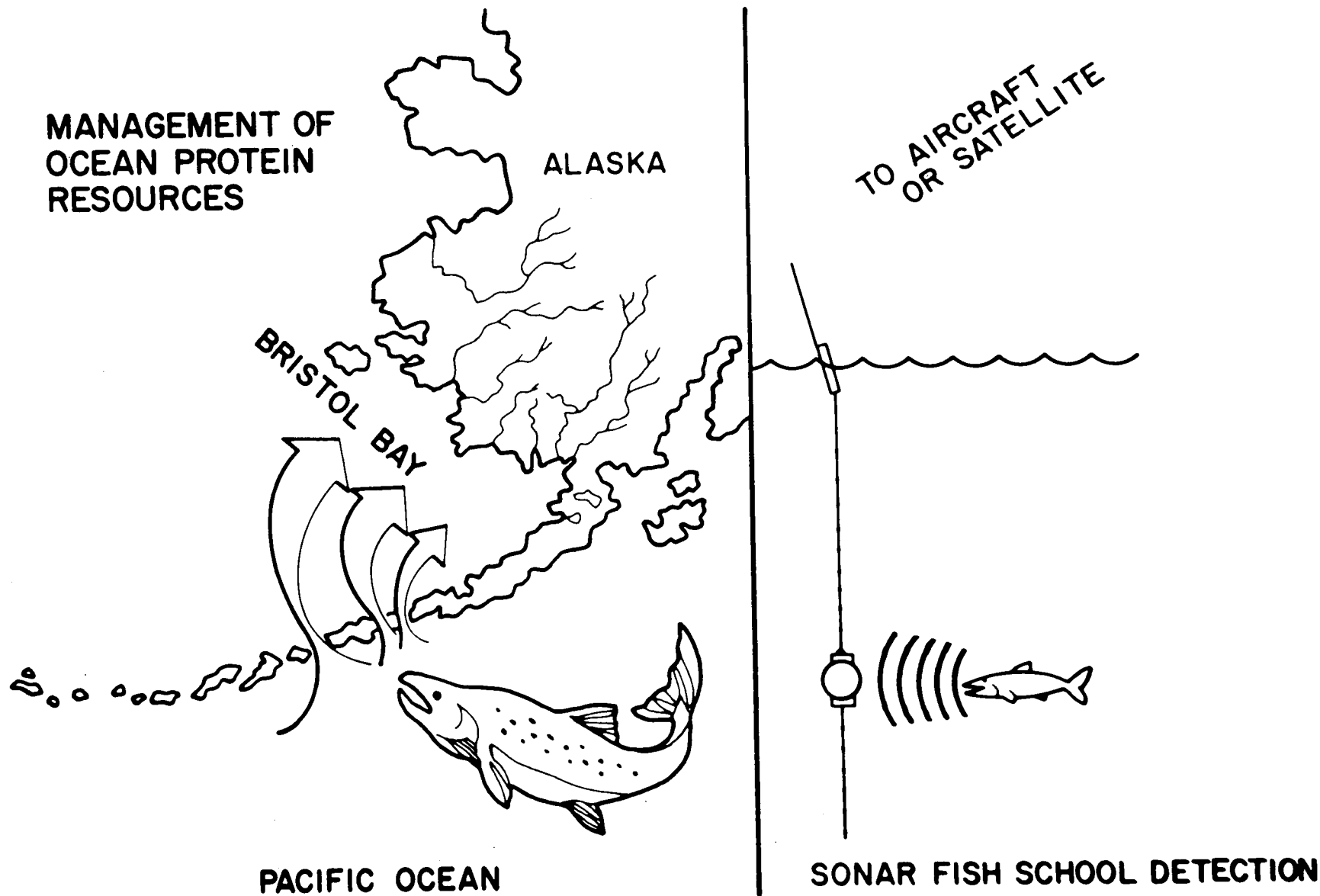




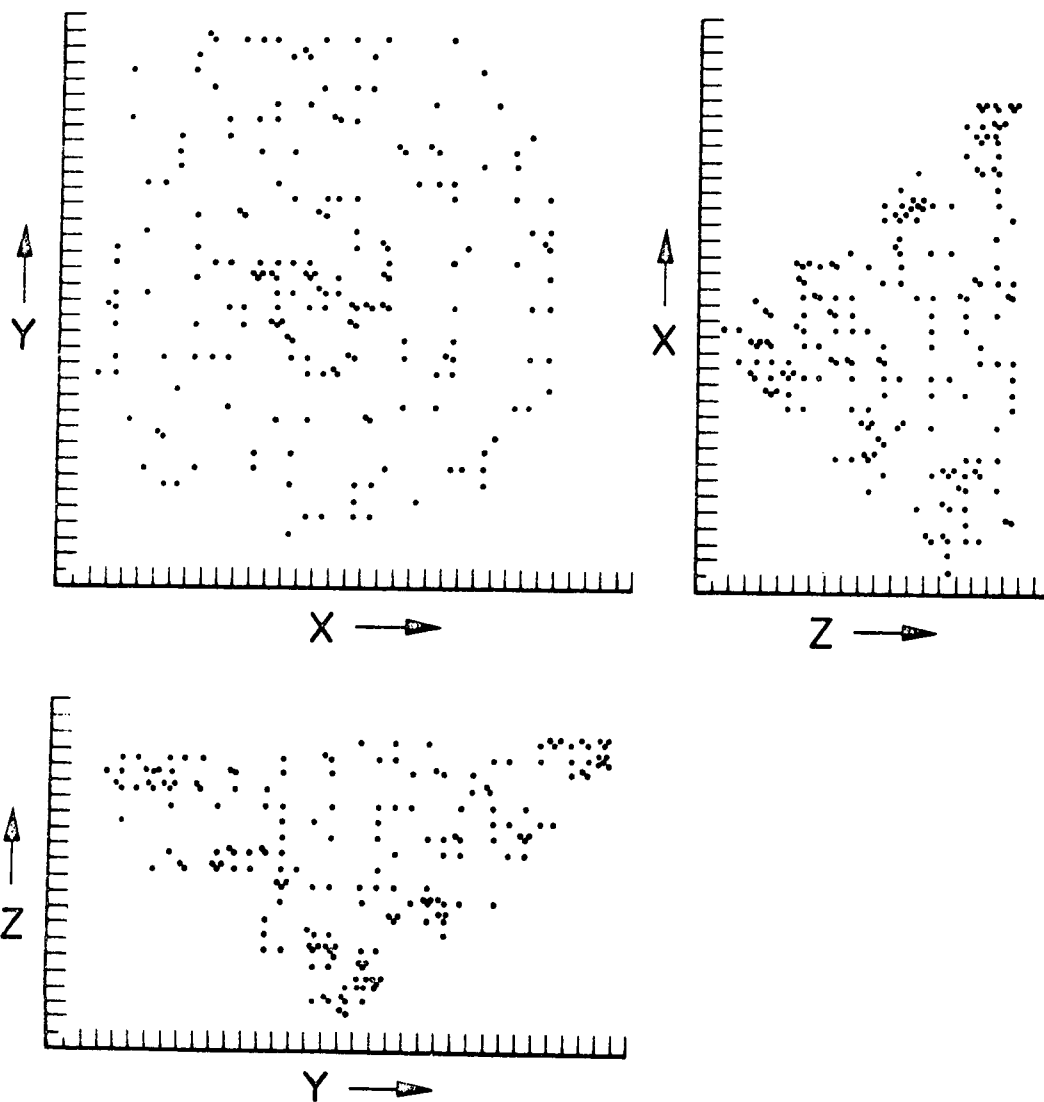








TWO DIMENSIONAL PLOTS OF THREE DIMENSIONAL DATA



"THREE DIMENSIONAL" PLOT OF DATA FROM A NOISY SPIRAL

